



Fardoulis, J. S., Smith, D., Payton, O., Scott, T., Freer, J., & Day, J. (2017). Deploying Low Cost, Small Unmanned Aerial Systems in Humanitarian Mine Action. In A. Brkljačić, & S. Vakula (Eds.), *The 14th International Symposium "MINE ACTION 2017"* (pp. 111-118). (Book of Papers (International symposium "Mine Action")).
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Deploying Low Cost, Small Unmanned Aerial Systems in Humanitarian Mine Action

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Abstract: Small unmanned aerial systems (sUAS's), which are made up of an unmanned aerial vehicle (UAV or 'drone'), a payload, ground control system, live video feed and other peripherals, can provide great utility in humanitarian mine action (HMA). Uses include: site overviews for pre-deployment planning and progress reporting during clearance operations; up-to-date, high resolution situational information and reconnaissance; evidence gathering as part of the non-technical survey (NTS) process; and real time video feeds during explosive ordnance disposal (EOD) & improvised explosive device (IED) operations.

sUAS's can help improve safety, increase productivity, make reporting more transparent, and provide better quality information to aid decision making during the land release process. This paper presents sample data outputs from low cost, off-the-shelf mini sUAS's, ranging from overhead snapshots, through to high resolution cartography and detailed GIS information. Tests were conducted using both standard imaging and GIS capabilities, plus near-infrared modified cameras that show better vegetation contrast. These results can be achieved using readily available commercial sUAS's with a take-off weight of less than 2kg.

Even though a number of past sUAS research projects have been undertaken in the HMA sector, the next step is addressing deployment challenges. Requirements such as creating standard operating procedures (SOP's), developing training programs, gaining permission to operate from national authorities, and investment in the infrastructure required to support each sUAS programme are addressed. The popularity of UAV's as a consumer electronics device means that millions of units are now being sold each year. However, there has only been limited deployment on a routine basis, without integration into standard HMA operations. The issues limiting the application of sUAS's will be addressed.

Keywords: UAS, UAV, RPAS, drone, remote sensing, photogrammetry, aerial survey, mapping, GIS, EOD, IED, humanitarian mine action

Introduction

A multirotor, small unmanned aerial system (sUAS), is generally an electronic aircraft system kept aloft by multiple propellers, four, when in a quadcopter configuration. Being able to accurately position such a system in three dimensional space has made multirotor sUAS's popular for imaging and surveying uses ranging from airborne real estate photography to aerial archaeology.

A number of trials have taken place using airborne platforms in humanitarian mine action (HMA)^{[1][2][3][4][5][6]}, helping demonstrate key advantages of either an airborne camera, sensors or mapping platform. This paper builds on such findings in relation to a category of multirotor sUAS

that are low cost, with a retail price of under 3,500 USD and a flying weight of less than 2kg. One of the most popular mini sUAS's is a DJI Phantom quadcopter, with the latest model in the series being the Phantom 4 Professional^[7], with a take-off weight of 1.4kg (Fig.1). A gyroscopically stabilised 20 Megapixel camera is included, with an auto pilot and flight time of up to 30 minutes.



Figure 1: Shows a 1.4kg, DJI Phantom 4 Professional, mini-size quadcopter. Image credit www.dji.com.

sUAS's like this can assist HMA and explosive remnants of war (ERW) reduction programs in many different ways, offering utility ranging from simple aerial snapshots to detailed geographical information system (GIS) outputs and forward-looking reconnaissance. Manual pilot input is via a handheld controller, with a real-time video stream displayed on a tablet or other type of monitor. Many sUAS's are also capable of flying pre-programmed waypoint missions, controlled via a PC, tablet device or smartphone. A number of sensors enable self-stabilizing capabilities for the aircraft to maintain a precise hover, supplemented by added camera stability offered by a gyro-stabilized gimbal.

Survey, Intelligence Gathering & Situational Awareness

Research into the use of sUAS's for landmine detection is ongoing however the use of commercial, off-the-shelf (COTS) micro sUAS's as a survey and intelligence gathering tool is possible with existing available technology. The primary sensor is an optical camera, capturing imagery and video in the visible light spectrum. On most digital cameras, the performance can be improved by removing the infrared blocking filter which results in enhanced sensitivity to the very near infrared. Vegetation typically has a strong reflection in the near infrared, known as the 'red-edge'. Modifying the camera to make it sensitive in this region provides significantly better vegetation contrast, as shown in Figure 3 and Figure 6.

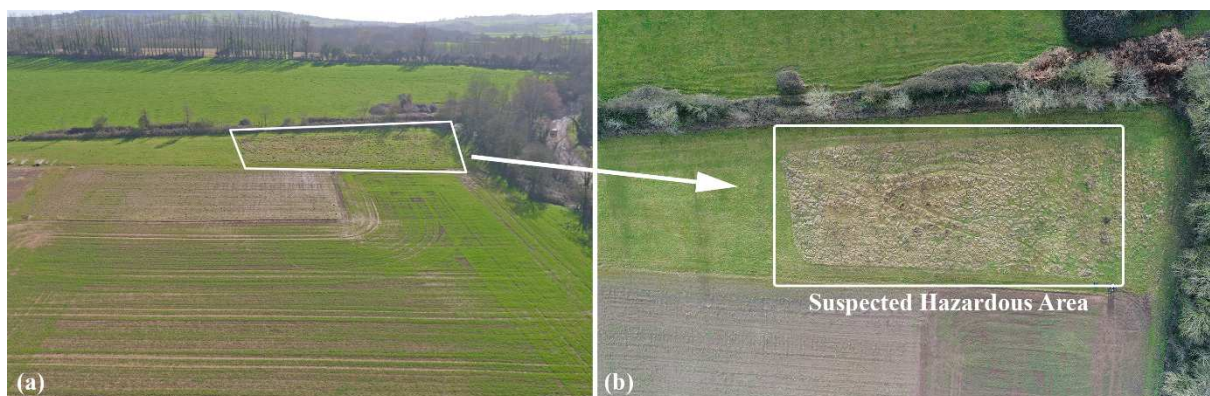


Figure 2: Shows (a) evidence of land use, most of the area is being farmed. And (b) the suspected hazardous area (SHA) in relation to land used for farming.

Objects may be spotted that represent direct evidence of explosive hazards, in addition to capturing secondary evidence and providing situational awareness. Gathering visual evidence fits within the scope of non-technical survey (NTS), with a sUAS being a tool that helps deliver a form of NTS+. Up-to-date, high resolution aerial imagery (Fig. 2) can complement other sources of information such as the history of a conflict, battlefield maps, information from combatants and local informants, in addition to observations made on the ground by members of a NTS team.

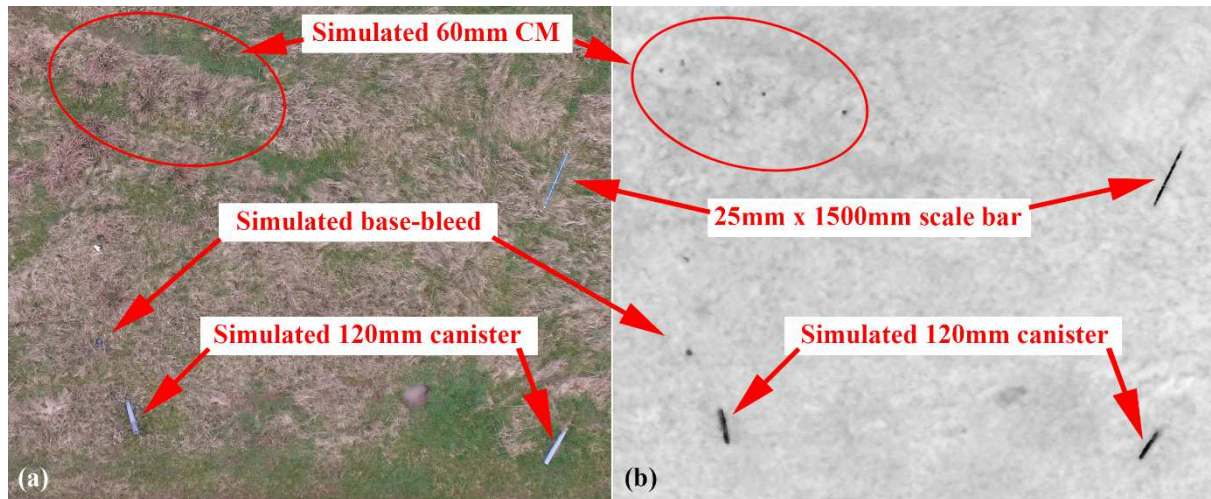


Figure 3: Shows evidence captured from a height of 20m. Image (a) is a standard photo. Image (b) is a 'red-edge' processed photo from a modified camera for better vegetation contrast.

Risk Assessment & Planning

The scope for sUAS's goes beyond NTS, as up-to-date, high quality situational information is also useful for pre-deployment planning during clearance operations, risk assessments, progress reporting, quality assurance and site monitoring. Speed is a major advantage for reporting and planning, with a single overhead snapshot only taking minutes to capture, less time than it would take to walk around the perimeter of clearance operations. Snapshots taken on a routine basis can

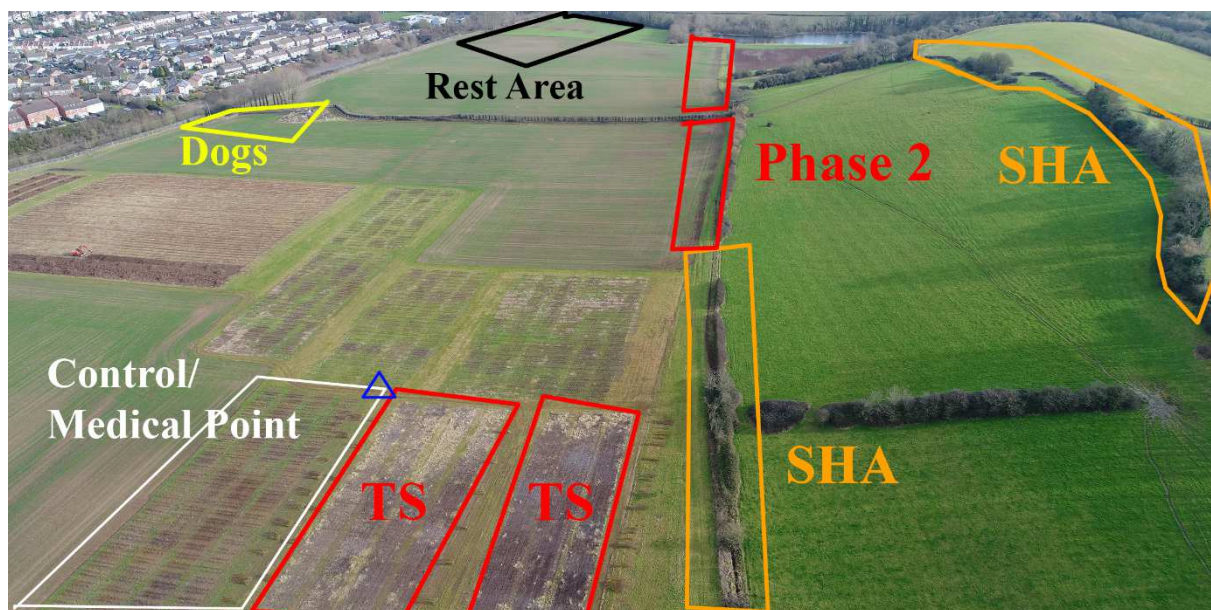


Figure 4: Shows how an up-to-date, high resolution sUAS image can be used for pre-deployment planning.

be used for a time-series analysis of progress during operations. Satellite imagery may not exist for certain locations or be obsolete, so an up-to-date, high resolution site overview can provide many advantages during pre-deployment planning.



Figure 5: Shows how overhead visibility for a roof inspection can be valuable in a complex urban environment. This example shows evidence of a cluster munition strike. Image credit: Andy Smith.

Access to Difficult Locations

Areas of interest can be difficult to access due to rugged terrain, obstructions, or complex environments, such as compromised, multi storey buildings in urban post-conflict environments (Fig. 5). In many cases, reconnaissance and evidence gathering from above will assist the quality of reporting and may improve safety. Being able to inspect roofs, fly over obstacles and difficult terrain can also mean faster access to visual evidence.

Very Close Inspection

A mini sUAS is in effect a small flying robot, being able to move around an object to gain forward looking reconnaissance via a live video feed, storing 4k video on an internal memory card. The sUAS

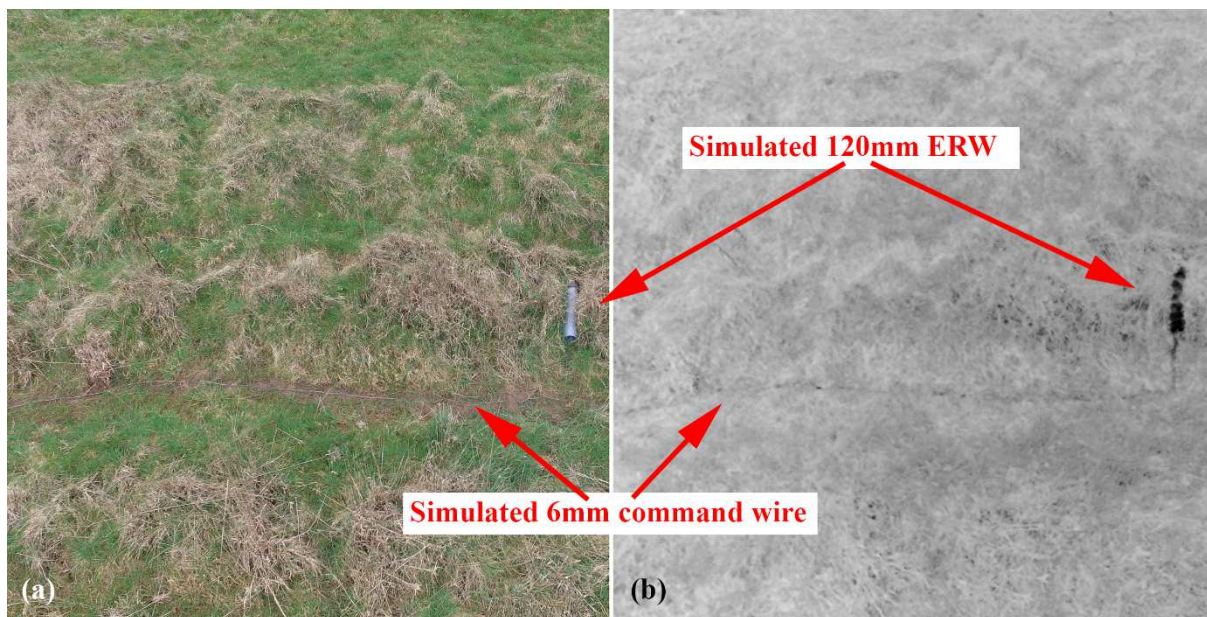


Figure 6: Shows close reconnaissance from 3m above the ground. Photo (a) is from a standard camera. Photo (b) is from a 'red-edge' modified camera for better vegetation contrast.

can hover in a stationary position or fly around suspect objects (Fig. 6), tilting the camera up or down. Pan can be achieved by either rotating the sUAS, or in some cases, separate camera control is possible by a second operator.

The cost of a sUAS is a fraction of that of ground robots used in EOD operations and is within the reach of humanitarian budgets. Some operators may find a mini sUAS to be a useful tool for forward looking intelligence during high-risk operations, particularly in environments where asymmetric conflicts took place. Very close reconnaissance would be an advanced, Level 3 operation (Fig. 8), due to risk and reduced stand-off distances from objects and the ground.

GIS Capabilities

Capabilities go beyond just taking photos and video, even from a 1.4kg, micro quadcopter. Many sUAS's incorporate a sophisticated autopilot, which makes pre-programmed waypoint flying possible. During a waypoint mission, the sUAS can fly a set pattern in strips over an area of interest, capturing images at a set altitude, with a predetermined amount of overlap between lane widths. Images are then stitched together and converted into a high resolution orthomosaic, point cloud, digital surface model and three dimensional representation of the environment. Resolution can be less than a centimetre per pixel, with the ability to create topographic maps with sub centimetre contours. In this case, the sUAS becomes an ad-hoc, high resolution GIS and cartography tool (Fig. 7).

At a basic level, quadcopters like the Phantom series of quadcopter[7] also geotag photos, embedding GPS coordinates regarding the location of each shot, which can be useful for a number of HMA uses, particularly NTS reports.

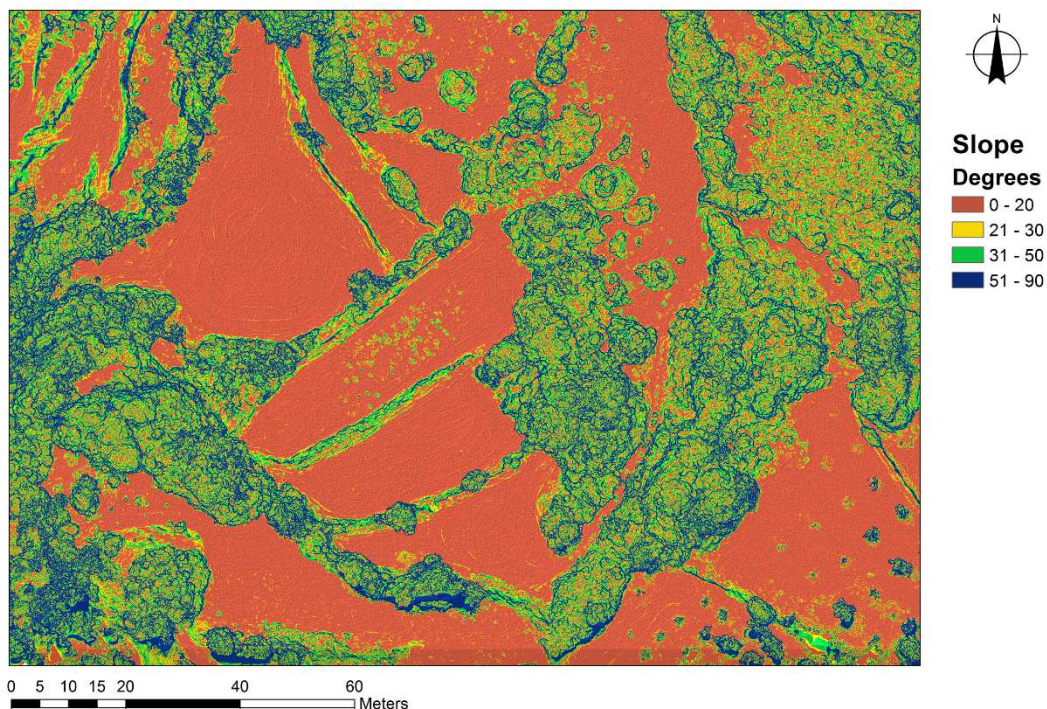


Figure 7: Shows an example of advanced GIS and cartographic capabilities from a micro sUAS. A map of the terrain has been made to indicate where a demining machine can operate, with an incline of up to 20 degrees.

Value to HMA Sector

New models of mini sUAS's on sale today perform better than predecessors but previous models have been capable of delivering similar benefits for several years now. Deployment has been limited in HMA compared to the uptake for surveying and inspection in other industries, with many

deployment challenges needing to be addressed. Embedding trials, with a qualified sUAS operator taking part in routine operations even for a limited period of time would be one way to gain relevant, demonstrable data to help prove the validity of such a tool. There is also a need for NGO's and national authorities to share knowledge, ideally through sUAS case-studies, for the benefit of the HMA sector overall.

Standard Operating Procedures & Training

As with other humanitarian demining operations, a partnership should be established with national mine action authorities in the trial of, and eventual deployment of sUAS's. There is a lot to gain, particularly as better quality information can lead to more informed decisions.

To aid the HMA sector in writing standard operating procedures (SOP's), a set of example operational parameters based on standards set by major aviation authorities around the world, combined with experience from commercial operations in the civilian UAS sector are listed in Figure 8. A framework for three levels of operations has been established, from Level 1 for standard operations, through to Level 3 for higher risk missions. A modular structure has been utilized, in a similar way to how EOD training and operating limits are set. The aim is to deploy in stages, and launch at Level 1 without delay, whilst providing pilots sufficient training and minimising risk.

Risks for new pilots include: collision with objects such as a tree branches, losing orientation, or loss of signal by flying too far away, or operating in environmental conditions beyond the operator's skill level. Potential risks are addressed by creating a parameter specifying the minimum operational separation from structures, people and the ground, plus limits regarding maximum distance and defining an operational weather envelope for each level. Smaller, lighter sUAS's pose less risk in the case of a malfunction or collision, with weight limits indexed to operator competency. There is general consensus that a sub 2kg object poses a low risk of explosion if it was to fall onto a mine field. However, there will be a moral issue of leaving a small flying machine in a hazardous area where a child or member of the local community might try and retrieve it. Hence, a procedure is needed in a SOP to deal with a lost sUAS, such as having an EOD team clear a lane to recover it.

Table 1 lists suggested training and testing requirements for validating pilot competency. It is recommended to distribute palm-size nano quadcopters to potential candidates, as control stick movements are similar to outdoor sUAS's, for self-paced practise in advance. Those with aptitude could then participate in a Level 1 ground school, and then attend a flight school module. Competency should be tested at both ground and flight schools. A minimum amount of flying hours should also be logged prior to fieldwork in hazardous environments, and currency maintained in terms of a minimum amount of flight hours in the last three months, before work is undertaken after extended breaks.

Table 1: Training Recommendations				
Op Level	Ground School	Flight School	Pre-requisite	Min. Flying hours
Level 1	2 days	1 day	Nano flight test	2
Level 2	2 days	2 days	Level 1	10
Level 3	2 days	2 days	Level 2	30

Objective	Minimum Separation	Operator Level		
		UAS 1	UAS 2	UAS 3
Photo capture	30m	✓	✓	✓
Video capture	30m	✓	✓	✓
Inspection	30m	✓	✓	✓
Close Inspection	10m		✓	✓
Very Close Inspection	3m			✓
Waypoint flying (for GIS)			✓	✓
Max Wind speed		25 km/h	UAS limit	UAS limit
Maximum take-off weight		2kg	5kg	20kg
Minimum visibility		600m	300m	50m
Max Height ¹		120m	150m	300m
Max Distance (line of sight) ¹		300m	500m	1000m

Figure 8: Example multirotor sUAS operational parameters for deployment in HMA.

Summary

sUAS's commercially available today deliver all those capabilities listed, and more. Such a device should be a viable option in the HMA toolkit, and when targeted for specific uses, can provide additional safety and incremental value to operations, often in unique ways, not readily available through other methods.

Our primary recommendation is to find ways to increase confidence in the use of sUAS's by the HMA sector, with a view towards deploying low cost, low risk mini sUAS's at Level 1 as a starting point. A lot of value can be gained from Level 1 operations, from small, low cost products. Activities that lead to operational exposure for NGO's and mine action authorities are suggested, so both management and field staff can see a sUAS in action and appreciate the value of the real-world data that they can provide. Such demonstrations are very powerful.

Acknowledgement

The authors would like to thank the Find a Better Way charity (www.findabetterway.org.uk) for funding the project, which made work presented in this paper possible.

The following people deserve thanks for their assistance, guidance and insight.

Milan Bajić, Gary Breen, Inna Cruz, Helen Gray, Tamara Ivelja, Rabie Jawashi, Leonard Kaminski, Jorg Lobert, Sulaiman Mukahhal, Ed Rowe, Emmanuel Sauvage, Dave Sheridan, Andy Smith, Gary Toombs and Boris Wortmann.

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